U.S. Department of Agriculture Agricultural Research Service
January 1984

Agricultural Research

Tapping Reservoirs of Animal Disease Resistance

U.S. livestock producers lose billions of dollars annually as a result of animal diseases. In 1980, losses from cattle diseases alone amounted to an estimated $5 billion. This means that feed production from millions of acres of land is wasted; costs of production to farmers and ranchers rise needlessly; and consumers pay higher prices for meat, milk, and eggs at the marketplace.

Reservoirs of disease resistance exist in livestock, just as in plants, awaiting exploitation by animal scientists, according to Terry B. Kinney, Jr., ARS Administrator. As an example, a single cow in a herd in France survived an outbreak of foot-and-mouth disease in 1938. Fourteen years later, six descendants of the original resistant cow survived another outbreak that occurred in the same herd.

Such acute diseases as foot-and-mouth disease most reasonably may be countered with a growing arsenal of vaccines. But selective breeding may become an ideal way to protect animals from a chronic disease. Kinney's outlook is that radically new technology emerging from biomedical sciences may provide the means for identifying resistance without exposing the animals to the disease.

Breeding for disease resistance may prove to be a cost-effective counterpart to vaccination for maintaining herd health, says Robert R. Oltjen, director of the Roman L. Hruska U.S. Meat Animal Research Center (MARC), Clay Center, Nebr. The cost of preventing disease by veterinary means alone is rising and is limiting animal production in many areas of the world today.

Oltjen cites research results and trends leading to improved ways to capture disease-resistance traits in cattle, swine, sheep, and poultry. He says the rapidly developing field of immunogenics that paved the way for successful organ transplants now offers hope for identifying particular disease resistance in farm animals. This prospect alone could greatly enhance the progress of conventional breeding. But combined with embryo cloning, embryo transplanting, and genetic engineering technologies, the possibilities are even more extensive.

These new technologies will help animal scientists to employ principles used by plant scientists who are quite successful in developing disease-resistant plant varieties. Until now, breeding disease resistance in farm animals has been slowed by generation intervals of up to 5 years.

Here, in digest form, are some salient points Oltjen makes on trends and opportunities in breeding animals for disease resistance.

- Progress is being made with small animals such as poultry. Through breeding and selection, it has been shown that strains of chickens can be developed having genetic resistance to Marek's disease. Genetic resistance to Newcastle disease and pullorum disease has also been demonstrated in poultry.
- Notable achievements, although slow in coming, have been made in large animals also: Resistance to mastitis is being used in animal production today, and resistance to tuberculosis is known to be genetically controlled. Studies have confirmed that Zebu cattle are more resistant to tick-borne protozoan infections and high temperatures than are European breeds, and that genetic resistance is present in cattle against leukosis, intestinal worms, and pinkeye, and in sheep against scrapie and brucellosis.
- Scientists are aware of some inherited traits that are associated with resistance to diseases. Other genetic markers may be found. One example: A dark ring around a cow's eye is an indicator of resistance to cancer eye. And several body functions serve as markers or indicators; fever, digestive system enzymes, and tears are genetically controlled and are related to susceptibility.
- The likelihood of an animal's succumbing to certain diseases when stressed may be genetically regulated. Scientists at MARC and at several cooperating universities are studying stress in hogs; this and other research on stressed animals may help scientists understand the mechanisms of immunity and devise improved measures for preventing or treating diseases.
- Scientists at MARC and Oregon State University are evaluating the heritability of immunoglobulin concentrations in bovine colostrum and blood serum. They are studying the relationships of these fluids to other characteristics including calf survival and incidence of disease and growth rates in beef cattle.
- Basic research in immunogenetics is opening frontiers to identifying the genetic complex that regulates the ability of lymphocytes to detect an invasion of bacteria or viruses and launch a counterattack. A further understanding of this phenomenon is an important area of research.
- A modern technique for defining single antibodies directed to single sites on antigens—monoclonal antibody technique—has enabled scientists to study this area with more authority than previously. Some of the antibodies are cross-reactive among species, so technology that is perfected for cattle may transfer to other livestock such as swine, goats, or sheep.

In the decades ahead, Kinney says, we may be able to select progeny the day they are born by "interrogating" their cells, in a biological sense, and deciphering their potential for growth, disease resistance, metabolic efficiency, nutritional capacity, and physiological and reproductive ability.

Ben Hardin
Peoria, Ill.

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Vol. 32, No. 5
January 1984

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Agricultural Research is published 10 times per year by the Agricultural Research Service (ARS), U.S. Department of Agriculture, Washington, D.C. 20250. The Secretary of Agriculture has determined that the publication of this periodical is necessary in the transaction of the public business required by law of this Department. Use of funds for printing this periodical has been approved by the Director of the Office of Management and Budget through March 31, 1987. Send subscription orders to Superintendent of Documents, Government Printing Office, Washington, D.C. 20402. Information in this magazine is public property and may be reprinted without permission. Prints of photos are available to mass media; please order by month and photo number.

Magazine inquiries should be addressed to: The Editor, Information Staff, Room 318, Bldg. 005, Beltsville Agricultural Research Center-West, Beltsville, Md. 20705. Telephone: (301) 344-3280. When writing to request address changes or deletions, please include a recent address label.

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Cover: Creating monoclonal antibodies from cloned cells in culture media is a hit-and-miss proposition requiring time, patience, and a lot of microplate test wells. But perseverance usually beats the odds, and ARS scientists are finding highly specific antibodies that could lead to vastly improved diagnostic methods for many diseases of livestock and crops—and to vaccines against these diseases as well. Article begins on p. 8.
(0983W1195-20)

The Search for a Warm-Climate Potato

Instead of using 66 100-lb sacks of seed potatoes to plant 1 hectare (2.471 acres), horticulturist Sharad Phatak of the University of Georgia could plant the same area with one jar of 140,000 true potato seeds (TPS). (1083W1416-7A)

Hardy and adaptable, the ubiquitous potato can be found growing below sea level behind Dutch dikes and high in the Himalayas. Unfortunately, the only place the potato does not thrive is in regions where high temperature and moisture conditions are common. Many temperate-zone nations would benefit from the ability to grow potatoes, which are second only to rice as a source of dietary energy.

At the Georgia Coastal Plain Experiment Station in Tifton, Ga., soil scientist Casimir A. Jaworski is working with a multidisciplinary team of scientists and engineers on a variety of approaches to making potatoes growable in warm and humid regions.

Planting true potato seed (TPS) instead of seed tubers—the way potatoes are commonly planted in the United States—shows great promise as a way to circumvent less developed countries' lack of high-cost agricultural technology for planting potato seed tubers.

Only 50 to 100 grams of TPS are needed to direct-seed a hectare (2.47 acres), as opposed to the 3 metric tons of seed tubers that would be needed to plant the same area. (About 700,000 TPS are in a pound or 1,500 in a gram.)

However, one drawback to direct-seeding TPS in warm climates is that germination is poor and stands are erratic at temperatures exceeding 73°F (23°C). Jaworski's team has experimented with germinating TPS at optimum temperatures in the laboratory and using a gel-seeder for seeding. In cooperation with the University of Georgia, a gel-seeder operating on an air-pressure concept was developed specifically for this purpose.

The stands established with pregerminated seeds were superior to direct-seeded stands. The choice of cultivar was also important: certain TPS lines produced good plant stands at high temperatures. But more breeding is necessary to create more suitable lines, according to Jaworski.

"TPS lines designed for warm regions should produce a high yield of small tubers in a short growing season and have multiple pest resistance," says Jaworski. "Future TPS lines will

ARS soil scientist Casimir Jaworski (left) and plant pathologist Ronald Gitaitis (University of Georgia) evaluate two potato plants and a related wild species for resistance to bacterial wilt disease, another important factor for growing potatoes in warm and humid climates. (1083W1413-11)

be hybrids with high plant vigor, high tuber-forming ability, and acceptable tuber enlargement and yield."

Besides direct seeding, TPS permits a number of planting variations. Potatoes can be produced by transplanting seedlings grown from TPS, or by transplanting small TPS-produced tubers at high seeding rates. Today, China is producing some of its potatoes by transplanting seed tubers grown from TPS.

Working with the transplant approach, Jaworski and his cooperators have produced as many as 1.3 million field-grown potato transplants per hectare in a one-time harvest. However, he believes up to 2 million potato transplants per hectare can be produced with improved TPS lines, seed treatment, improved pest control, and perfection of cultural practices.

"We have obtained small tuber yields of 14 to 32 metric tons a hectare when seeding TPS at very high rates as in transplant production. The TPS line with the highest yield produced 3.28 million tubers a hectare and averaged less than 10 grams per tuber," says Jaworski.

The survival of bare-root potato transplants varies with the TPS line and temperature in the growing area. In tests in Canada, the survival rate of eight open-pollinated lines was 89 to 99 percent. Many of the same lines in Georgia had high survival rates immediately after transplanting but unacceptable rates by the time of tuber harvest. Further research is needed to develop lines and cultivars with high-temperature survival rates and other desirable characteristics.

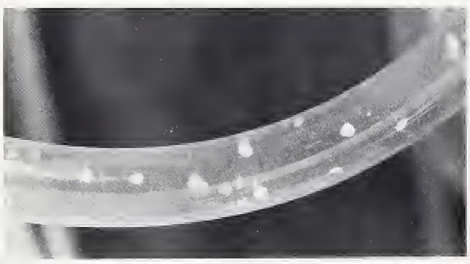
The researchers are also developing guidelines for storing bare-root potato transplants. Tests on loose-packed, bare-root potato transplants stored for 6 and 10 days showed that leaves retain their green color longer with less defoliation when stored at 35°F and 45°F (1.7°C and 7.2°C) than at higher temperatures. Plant survival and growth rates after transplanting were also higher with plants stored at 35°F and 45°F, compared with those stored at 55°F and 60°F (12.8°C and 15.6°C).

Another serious hurdle to overcome for successful potato production, especially in warm climates, is potatoes' susceptibility to bacterial wilt. This disease, also known as brown rot or southern bacterial wilt, affects potatoes in almost all temperate, semitropical, and tropical zones of the world. It limits the growing of potatoes and many other susceptible crops in parts of Asia, Africa, and South and Central America.

In the United States, the disease occurs in the Southeast from Virginia to Florida. It has rarely occurred in the Southwest or Midwest and has not been confirmed west of the Rocky Mountains. However, a low-temperature strain of *Pseudomonas solanacearum* recently became established on a native weed host in Sweden. The bacterial source was traced to infected tomato transplants from North Africa. With the presence of these low-temperature strains and the expansion of potato-growing areas, Jaworski predicts that the disease could begin to cause great losses worldwide over the next few decades.

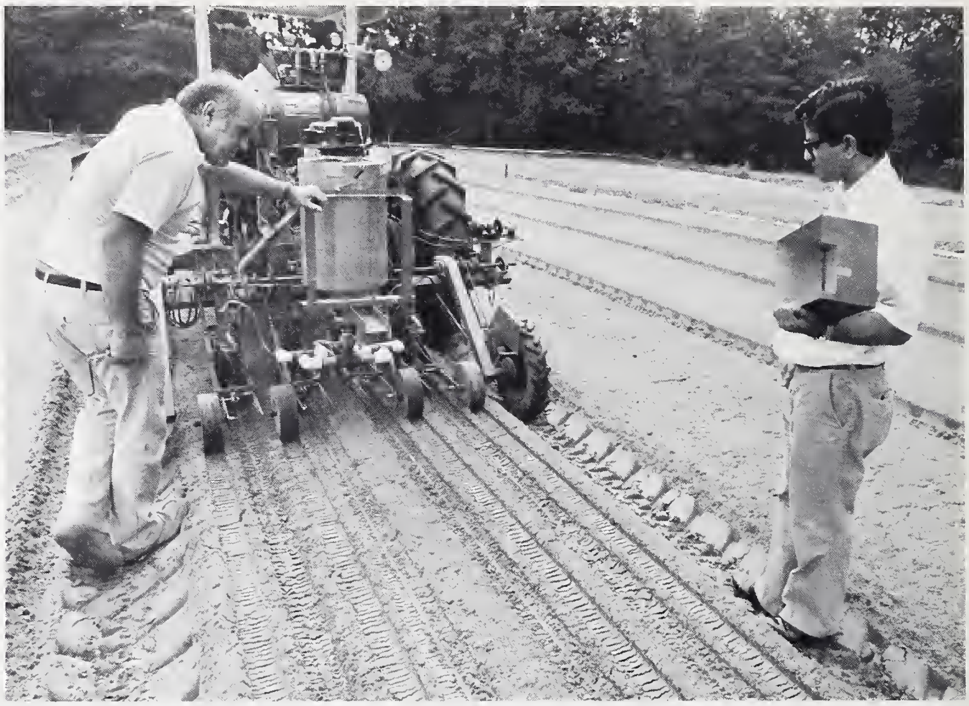
As a result of several years of research that Jaworski did in cooperation with the University of Georgia, effective screening techniques for detecting resistance in the field were developed. Subsequent breeding programs at the university recently culminated in the release of two *P. solanacearum* tolerant germplasm lines: *Solanum sucrense* PI 458391, BWT83, and Noordeling PI 109760, BWT83.

Other scientists involved in this cooperative research effort to extend potato production to warm, humid climates are University of Georgia scientists Sharad C. Phatak, horticulturist; Suhas R. Ghate, agricultural engineer; and Ronald D. Gitaitis, plant pathol-

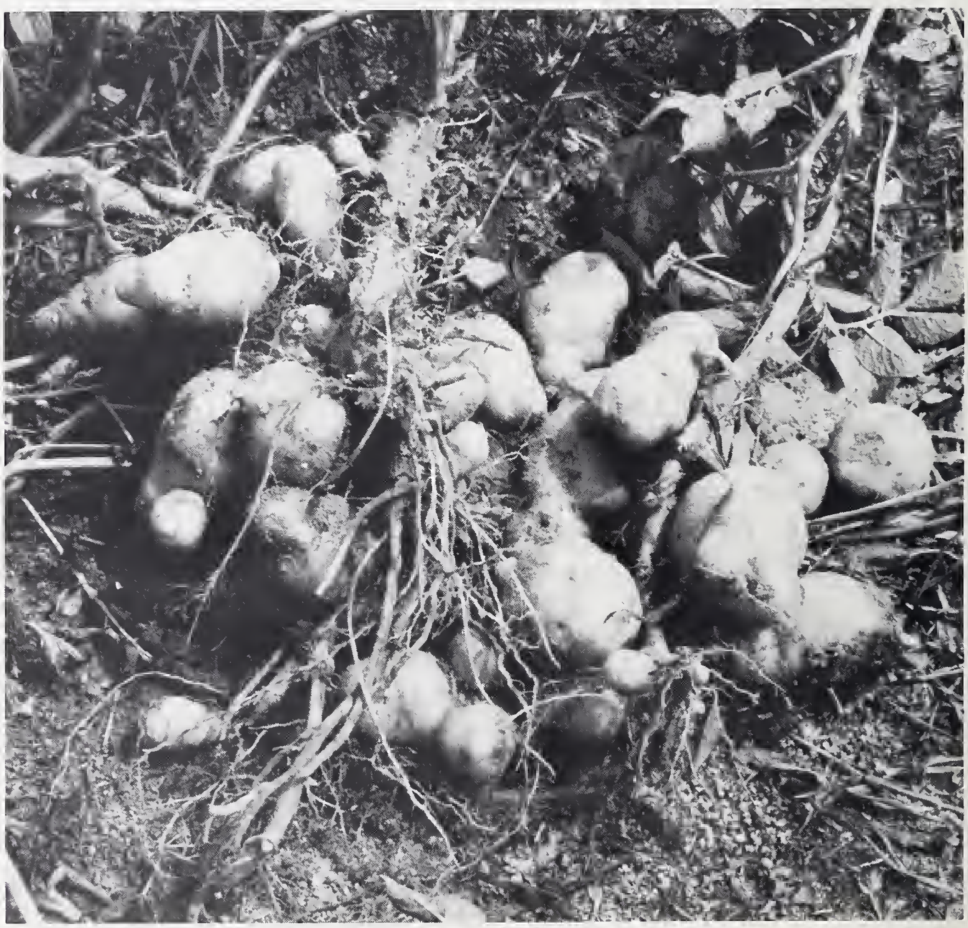


Top: Mechanical technician Charles Welsh (left) and agricultural engineer Suhas Ghate (both with the University of Georgia) mix pregerminated TPS into a gel solution for field tests using the compressed-air gel seeder that they designed and built. Plans for the seeder can be obtained from Ghate, Agricultural Engineering Department. (1083W1423-36)

Above: Suspended in a flowable gel, pregerminated TPS are carried through the delivery tubes of the seeder. (1083W1426-23)



Jaworski and Ghate check gelled trails of pregerminated TPS for proper flow and distribution from the automated seeder. (1083W1426-10)



Uprooted plants grown from hybrid TPS (provided by geneticist Stanley Peloquin, University of Wisconsin) show excellent tuberization and a wide range of tuber sizes. (PN-7078)

ogist. Larry Risse, ARS agricultural marketing specialist in Orlando, Fla., coordinated the potato transplant packaging, handling, and storage research. Albert Liptay, Agriculture Canada, Harrow, Ont., evaluated southern field-grown potato transplants under temperate conditions. ARS, other universities, and commercial potato breeders and geneticists are generously providing the TPS and tubers, which are essential to research success in developing a potato for hot climates.

Casimir A. Jaworski is located at the Georgia Coastal Plains Experiment Station, ARS-USDA, P.O. Box 748, Tifton, Ga. 31793.—(By Neal Duncan, New Orleans, La.) ■

Reducing Erosion From Thawing Soil

To gather statistically useful data on how various crop management practices affect runoff and erosion, agricultural engineer Donald McCool prepares to measure crop residues within a square-meter sampling frame. (0983X1274-6)

Some reports have estimated that up to 90 percent of the erosion on dry-farmed cropland in the Pacific Northwest each year is caused by rainfall and snowmelt on thawing soil. Other parts of the country suffer similar, but generally less severe, problems.

Five years of plot tests helped agricultural engineer Donald K. McCool determine the accuracy of these reports and show the effects of tillage and crop management practices on runoff and erosion under these conditions.

The most important finding was that the average amount of soil lost on no-till seeded and rough-tilled stubble plots was only 0.7 ton per acre, and for the reduced tillage plots only 1.8 tons per acre. This is a significant reduction from the 10-ton per acre average for the winter wheat after summer fallow plots.

The management practices McCool used included a winter wheat-summer fallow rotation under conventional tillage; a winter wheat-small grain rotation under reduced tillage and no-till; a winter wheat-pea rotation under reduced tillage and no-till; and rough-tilled stubble. He collected runoff and sediment from each rain or snowmelt occurrence and then divided the occurrences into two groups on the basis of whether or not the soil had frozen and thawed. He also reviewed 42 years of past erosion data from the region.

The results showed that when soil freezing was particularly severe—8 to 10 inches deep—total runoff from no-till, rough-tilled, and reduced tillage plots averaged 4 inches, compared to a 5-inch average for the conventionally seeded winter wheat after summer fallow plots.

When the soil frost was shallow—less than 4 inches—or not frozen at all, runoff and erosion were much less regardless of management practice. However, the runoff and erosion were both significantly lower under reduced and no-till treatments compared to the conventional winter wheat after summer fallow treatment.

Explains McCool, "Rough soil surfaces with substantial amounts of crop residue in a shallow frost situation create a discontinuous frost that allows infiltration of rainfall and snowmelt during thawing. Also, large quantities of crop residues insulate the soil and actually reduce frost penetration. Under fine-tilled conditions with only small amounts of surface residue, a concrete frost layer will form and allow little or no infiltration, even when the frost is shallow."

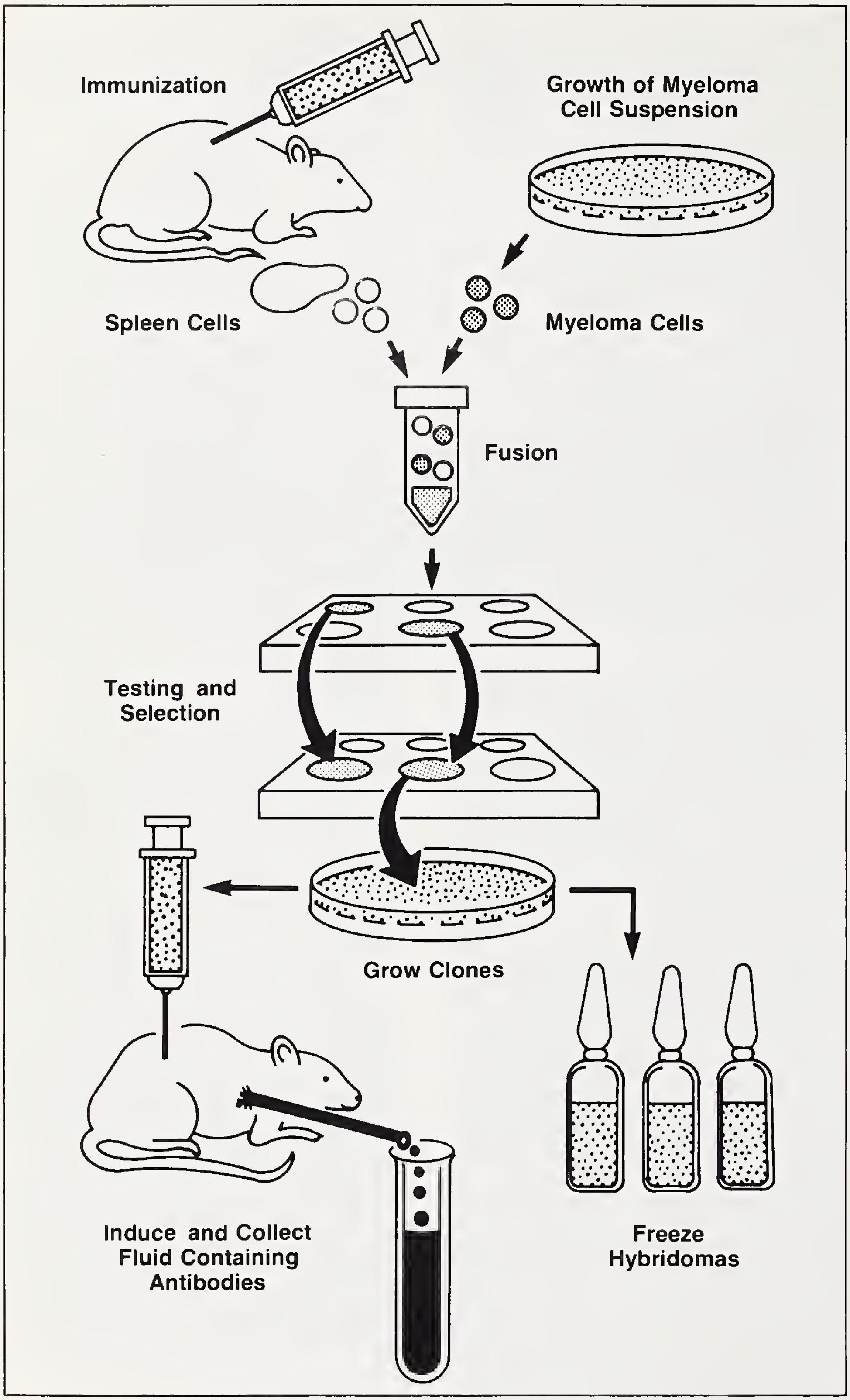
Compacted layers from tillage implements often intensify the problem. When a long cold period occurs, a deep concrete frost that is impermeable may be formed regardless of soil surface treatment. However, erosion will still be less under no-till or reduced tillage because surface roughness and residues increase the resistance to erosion.

McCool notes that contrary to the previous reports, his tests showed that only about 60 to 70 percent of the total yearly runoff and only about 50 percent of the annual soil loss to erosion are due to runoff from rainfall and snowmelt on frozen soil in this region under a conventionally tilled winter wheat-summer fallow system.

Donald K. McCool is located at the Washington State University, Johnson Hall, Pullman, Wash. 99164.—(By Lynn Yarris, Oakland, Calif.) ■

Amid the rolling hills of the Pacific Northwest, where soil erosion and runoff have been severe, a healthy crop of winter wheat emerges through the stubble of a no-till field that will probably lose less topsoil than the conventionally tilled field in the background. (0483X338-23)

Monoclonal Antibodies: Probing the Mysteries of Immunity



To produce monoclonal antibodies, spleen cells from a mouse immunized against a specific disease are fused with mouse tumor (myeloma) cells to create hybrid cells (hybridoma) that grow in culture. The hybridoma cells are then screened for the production of antibodies. Hybridomas that test positive are injected into a mouse, and the mouse becomes a living factory for the production of antibodies against the same disease. Other positive hybridomas are frozen for future use. (PN-7080)

A relative newcomer to the world of basic research, a technique for producing specific disease antibodies is quickly expanding the horizons of animal and plant disease prevention.

The process, called the hybridoma technique, makes possible earlier and more accurate detection of plant and animal diseases, speeds research progress, and is the basis for applied research into the development of vaccines. The National Institutes of Health and other laboratories are using the technique in research on human diseases as well.

The first step in the relatively new process of producing specific disease antibodies—called monoclonal antibodies—is to inject a specific disease-causing agent—for example, a bacterium, virus, parasite, or tumor antigen—into a mouse. The mouse, in response, begins to produce specific antibodies to the antigen, developing an immunity to the disease. An antibody-producing cell is then removed from the mouse's spleen and fused with mouse cancer cells, called myelomas, which enable the hybrid cells—called hybridomas—to survive under laboratory conditions. The hybridomas are then cloned to create additional, identical hybrid cells. These cells mass-produce specific antibodies almost indefinitely—either in a mouse into which they have been injected, or in laboratory culture. The antibodies are called monoclonal because the hybrid cells producing them trace back to a single spleen cell.

The great specificity of monoclonal antibodies is an important key to unraveling the mysteries of the immune system. The technique is also vastly more efficient: once a monoclonal antiserum is produced it can be frozen and reactivated as necessary, avoiding the costly and time-consuming purification process with polyclonal antibodies that hampered earlier research and diagnosis.

ARS scientists are using monoclonals experimentally to detect both animal and plant diseases and to study proteins that may form the basis for new animal vaccines. Since the antibodies are specific for only one antigen, further research may make it

possible to combine them with drugs and have them deliver medication directly to disease-causing organisms, somewhat like biological "smart bombs" or guided missiles.

Such specificity has also enabled scientists to use monoclonal antibodies as excellent diagnostic tools by combining them with radioactive tracers, fluorescent stains, or enzymes, and observing their actions in living organisms.

The hybridoma technique has also made possible a breakthrough in animal science—the ability to fuse cells from two different species, such as from a cow and a mouse, to make hybridomas.

"Since cattle are not susceptible to myelomas, we fused mouse hybridomas with antibody-producing bovine spleen cells," says animal scientist Albert Guidry of the Milk Secretion and Mastitis Laboratory, Beltsville, Md.

"Monoclonal antibodies produced by these hybridomas are the first ever resulting from the fusion of bovine cells and cells from another species," says Guidry, who collaborated on a research team with Subramanian Srikumaran and Richard Goldsby of the University of Maryland, College Park, Md. (both now with Amherst College in Massachusetts).

"Bovine monoclonal antibodies will be used to measure the immunity of cattle to mastitis. Knowledge obtained by using these antibodies to study natural defenses against mastitis may show how to immunize cattle against this disease," Guidry says.

Exploring disease mechanisms with monoclonal antibodies is not limited to animals: with plants, the technique is almost the same. A plant disease causing agent can be injected into a mouse, which produces antibodies to fight it. An antibody-producing cell is taken from the mouse's spleen, cloned, and fused with mouse myeloma cells. The hybridomas then mass-produce antibodies to that particular plant disease.

"We now have monoclonal antibodies for a virus that infects stone fruits; it causes a disease called prunus necrotic ring spot," says researcher Hei-Ti Hsu of the American Type Culture Collection (ATCC), a private firm in Rockville, Md., which is cooperating with ARS in this research.

Animal scientist Albert Guidry infuses a cow's udder with mastitis-causing pathogens. Subsequent tests with monoclonal antibodies will help Guidry identify potential sources of resistance to the disease. (1083W1395-12)

Traditionally, in order to obtain virus-free fruit trees, it has been necessary to graft tissue from the fruit stock onto indicator plants and wait for symptoms of infection to appear. This test normally takes 6 to 8 weeks to complete. "Now laboratory technicians, using monoclonal antibodies, can test hundreds of samples of fruit stock for virus infection in a single day," says Hsu.

Monoclonal antibodies have also been developed for viruses that infect

The use of monoclonal antibodies in serological tests for trichinosis—purely experimental at this time—provides zoologist Ray Gamble with a highly accurate method of identifying infected swine. (1283W1664-20)

Hei-Ti Hsu, a plant virologist with the American Type Culture Collection (ATCC), checks the temperature of liquid nitrogen storage tanks in which hybridomas are preserved that secrete antibodies against certain plant viruses. (1083W1393-4)

apples, tobacco, roses, alfalfa, blackberries, carnations, raspberries, oranges, and tulips in the ARS-ATCC cooperative project.

The use of monoclonal antibodies to help in the fight against animal and plant disease is relatively new, and much basic and applied research must be done to realize fully the potential of this new technology. But the results thus far indicate that this powerful tool may foster dynamic new approaches to preventing some of the most destructive plant and animal diseases.

Albert Guidry is located at the Milk Secretion and Mastitis Laboratory, Bldg. 173, Beltsville Agricultural Research Center-East, Beltsville, Md.—(By Vince Mazzola, Beltsville, Md.) ■

Monoclonal Antibodies at Work

Putting the benefits of the hybridoma technique to work, ARS scientists have made progress in basic animal disease research that lays the groundwork for the development of vaccines by commercial laboratories.

This past July, microbiologist Harry D. Danforth announced that ARS had entered into an agreement with three genetic-engineering companies to provide them with monoclonal antibodies against various parasitic organisms that cause coccidiosis. This disease infects chickens' intestines, and annually costs U.S. poultry producers more than $150 million in direct losses and about $100 million for anticoccidial drugs.

"We now have cloned cell lines producing antibodies specifically against *Eimeria tenella*, one of the most virulent forms of chicken coccidiosis," says Danforth, who works at the Animal Parasitology Institute, Beltsville, Md. "We have also produced monoclonal antibodies against many other species of chicken and turkey coccidia."

The three firms will use the antibodies to identify and produce genetically engineered proteins, or antigens. The proteins are required as a first step in devising a potential vaccine against the disease. According to Danforth, it is not yet possible to predict when such a vaccine might become commercially available.

The fight against the virus that causes bluetongue, a disease of cattle and sheep, is also being helped by the hybridoma technique. At the high-security Plum Island Animal Disease Center, microbiologist Judith Appleton and research veterinarian Geoffrey Letchworth (now at Cornell and the University of Wisconsin, respectively) developed monoclonal antibodies against the virus. In preliminary experiments, a laboratory-produced antibody protected four sheep from one bluetongue virus strain (BTV type 17). Using this antibody, they also identified a protein in the virus' outer coat that commercial laboratories might use for developing a new vaccine.

A photomicrograph shows spleen cells of a mouse immunized against chicken coccidiosis fusing with larger myeloma cells from another mouse to create hybridomas. Some of these hybridomas will secrete antibodies to the disease. (PN-7081)

"Bluetongue costs the U.S. livestock industry $30 million yearly in sales of cattle, semen, and embryos to overseas markets that fear introduction of the disease," says Appleton. "An effective bluetongue vaccine would go a long way toward lifting these trade barriers."

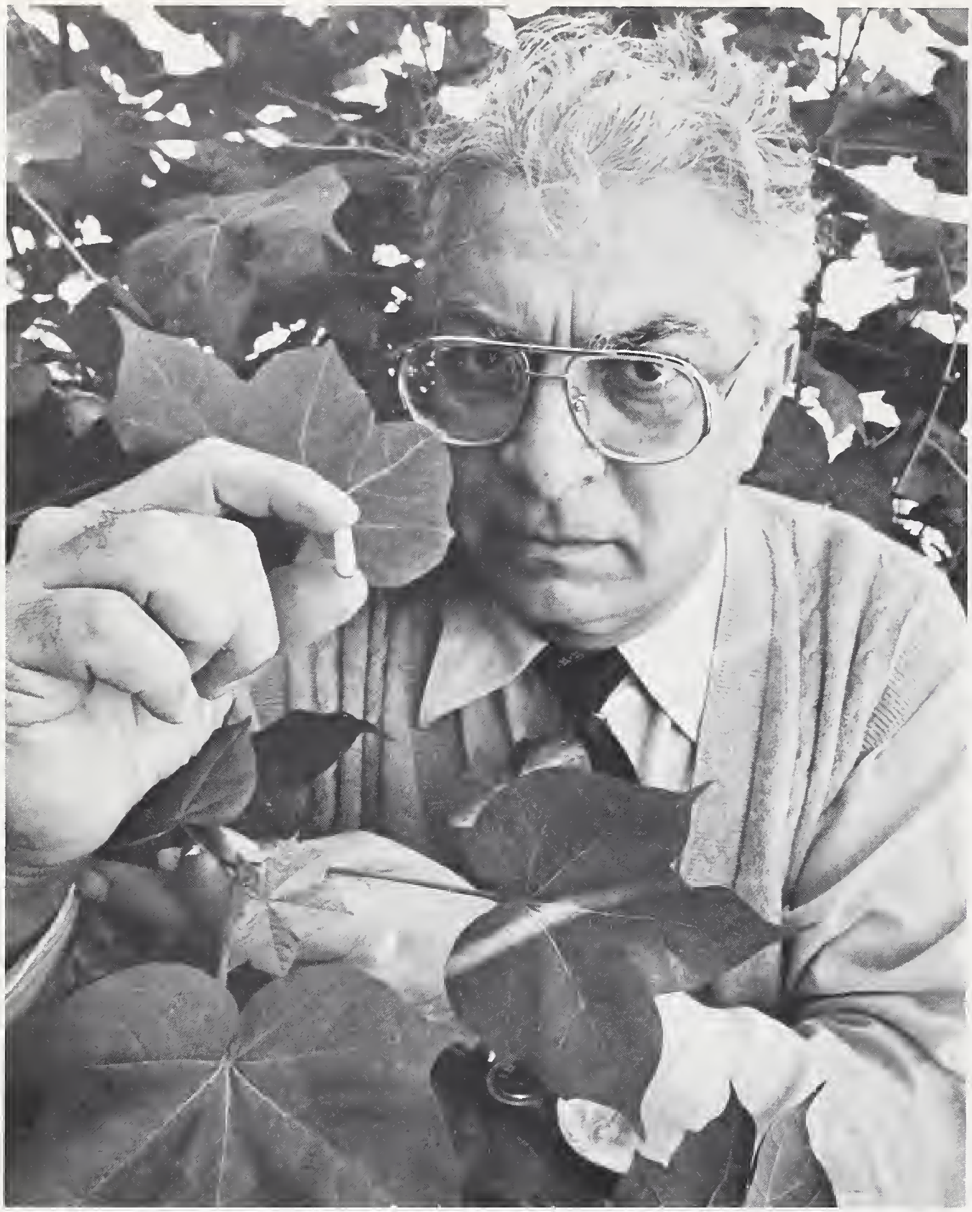
In related research, ARS scientists are laying the groundwork for a cheaper, more convenient way to test swine for trichinosis.

"We are presently testing monoclonal antibodies in a serological test for trichinosis," says H. Ray Gamble of the Nonruminant Parasitic Diseases Laboratory in Beltsville, Md.

"These antibodies have proven to be extremely accurate in identifying infected swine. Much testing must be done before a practical test will become a reality. However, such a test would permit U.S. pork producers to export to foreign countries that now restrict importation of our pork."—*(V.M.)* ■

To test their effectiveness against coccidiosis, microbiologist Harry Danforth prepares to inject hybridoma-produced coccidia antibodies into poultry (1083W1397-21)

Microbial Insecticides: Finding Insects' Weaknesses



Inside this tiny water-soluble capsule held by insect pathologist Carlo Ignoffo are 250 mg of powdered *Heliothis* NPV—enough viral insecticide to spray and protect an entire acre of cotton plants against the cotton bollworm and budworm. (1283X1646-10)

The first viral insecticide—if used to control bollworms and budworms on all U.S. cotton acreage—could replace more than a million pounds of chemical insecticides on a crop grown on more than 13 million acres annually in this Nation.

The same microbial insecticide has been approved for use, not only against the two major *Heliothis* insects on cotton, but also for control of the same insect species on corn, soybeans, sorghum, and tomatoes—namely, the earworm, podworm, and fruitworm. Another species of *Heliothis*, the tobacco budworm, is also susceptible to the same virus.

These six crops are grown on about 180 million acres, 45 percent of this Nation's cropland, each year.

"*Heliothis* insects are a worldwide problem," says Carlo M. Ignoffo, director of ARS's Biological Control of Insects Laboratory, Columbia, Mo., who conceived and developed the first viral insecticide—*Heliothis* NPV (nuclear polyhedrosis virus)—for use against cotton insects. "They attack and damage about 30 different commodities, all but a few of which are important to the U.S. economy.

"The potential for use of microbial insecticides is dramatic," says Ignoffo. "The viral insecticide can be effective and specific against *Heliothis* insects that damage 9 field crops, 13 vegetable crops, 4 fruit crops, as well as hemp, peppermint, pines, poppy, and tobacco."

But the potential goes far beyond just this viral insecticide, Ignoffo continues. "More than 1,000 naturally occurring microorganisms or their products, including viruses, bacteria, fungi, and protozoa, could hold promise for the control of major insect pests."

At least 10 microorganisms or their products have been registered by the Environmental Protection Agency since 1962 when the bacteria, *Bacillis thuringiensis (Bt)* was approved for use against caterpillar pests on several crops. ARS research has shown that *Bt* is effective against the corn borer and cabbage looper, and larvae of the Colorado potato beetle, Mexican bean beetle, mosquitoes, and such stored-grain pests as the Indian meal moth and almond moth.

Ignoffo, an insect pathologist, says State, Federal, and industry researchers have developed and registered for use by growers a wide range of effective and unique microbial insecticides besides *Bt* and the *Heliothis* virus. Here are three examples:

- A protozoan for use in baits against grasshoppers on rangeland;
- Viruses against the tussock moth in conifers and the gypsy moth larvae in hardwood forests;
- Fungi or molds against mites of citrus, and aphids and whiteflies attacking flowers in greenhouses.

"But it strikes me as misleading to tick off these new controls in such an offhand way," Ignoffo says, "without placing their development in perspective.

"The men and women responsible for these milestones have spent years studying the habits and characteristics of both the target insects and their parasitic microorganisms. They have to know the details of target insects' life cycle—how and when they reproduce,

A *Heliothis zea* caterpillar, commonly known as the cotton bollworm, eats its way into an unprotected cotton boll. (1283X1652-26)

Overcome by a viral insecticide, a *Heliothis zea* caterpillar hangs from the boll of a viral-protected cotton plant. At the slightest touch the caterpillar will rupture to release billions of additional virus particles that could spread to protect other plants as well. (1283X1651-7)

when they emerge as larvae, what their feeding habits are, what makes them most vulnerable to attack, and how long it takes for a disease to immobilize them."

He cites as an example a biocontrol in another scientific discipline, plant pathology. Some pathogenic fungi attack and destroy food crops; other fungi attack and control the pathogenic fungi of crops. Plant pathologists must know the difference.

Scientists at the Beltsville Agricultural Research Center discovered that one fungus (*Talaromyces flavus*) attacks and destroys the fungus (*Verticillium albo-atrum*) that causes verticillium wilt disease in cotton and potatoes. Damage from the wilt costs more than $150 million annually in losses in the two crops (see *Agricultural Research*, Nov. 1982, p. 13).

Ignoffo says cotton growers have been slow to accept the *Heliothis* virus as an insecticide because it takes 3 to 6 days for the disease to kill the bollworm and because older larvae are much less susceptible to the virus than are younger ones. "Chemical insecticides kill the bollworm within a matter of hours, by contrast, so timing is not as critical with a chemical as with a microbial insecticide."

Ignoffo says that the behavioral habits of *Heliothis* larvae on different commodities, corn, cotton, and soybeans, for example, also could affect the efficacy of a viral insecticide.

"*Heliothis* corn earworm moths lay their eggs directly on corn silks, and the young larvae penetrate the ear soon after hatching. The damaging larvae spend 90 percent of their lives in the protective confines of the ear feeding on immature kernels not exposed to the virus.

"This contrasts with podworms of soybeans, which are exposed as larvae for about 90 percent of their lives, and bollworms of cotton, exposed about 40 percent."

Then there are wide differences in activity, or viability, among strains of microbials. Because of this, all present commercial preparations of the *Heliothis* NPV trace directly to the original isolates selected by Ignoffo in 1961 and since maintained as the standard for virulence.

Knowledge of the microbial characteristics and virulence and habits of the insect are necessary pieces of a complex puzzle that are needed in order to obtain successful field results.

Beyond that, Ignoffo stresses that, no matter how successful microbial insecticides are or come to be, they represent only one alternative to controlling crop pests. Research must continue not only on microbial insecticides, but also on the use of predator and parasitic insects, crop resistance, cultural practices, pheromones or attractants, and selective pesticides, as examples. "We are learning to integrate these various approaches more effectively than in the past and with less pollution to the environment," he concludes.

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Corn Germplasm Resists Corn Borers

Entomologist Dean Barry dissects stalks of his new corn strain as he and research assistants Arnulfo Antonio (middle) and Chris Zirkle evaluate damage from second-generation European corn borers in an artificially infested plot. (1083X1401-18)

A source of corn germplasm that will resist the ravages of the second generation of European corn borers when the plants are flowering is now available to plant breeders. It is called MOECB2(S1)C5.

Until now, breeding of corn to hold the insect pest in check has been generally focused on using germplasm that resists attack of first-generation borers while corn is in the whorl stage, says ARS entomologist Dean Barry, Columbia, Mo.

ARS scientists in Mayaguez, P.R., and Ankeny, Iowa, and scientists of the Missouri Agricultural Experiment Station cooperated with Barry in developing MOECB2(S1)C5 through six selection cycles.

By the end of the third cycle of selection, second-generation borers tunneled an average of only 6 inches into stalks of the resistant corn. That's in contrast with 12 to 20 inches in susceptible cultivars and 10 inches in PR-Mo2, the resistant germplasm source that the scientists crossed with Mo-SQB to start recurrent selections.

The success that the scientists demonstrated in developing resistance to second-generation corn borers may encourage further breeding efforts.

One further encouraging note is that once corn hybrids with resistance to European corn borers are developed, perhaps no new race of the insect will evolve to break the resistance. Decades ago, ARS scientists at Ankeny began deliberately infesting young corn plants with first-generation borers to see if the resistance could be broken. It wasn't.

When corn with resistance to second-generation borers becomes commonplace, however, farmers should not let down their guard, says Barry. If every farmer planted resistant hybrids the corn borer population would be small, but a few borers would still survive the winter. If the next season a farmer planted a nonresistant hybrid, the borer population could rise rapidly, given the right conditions.

It is hoped that resistance to second-generation corn borers can be incorporated into high-yielding hybrids by commercial firms.

"Not too many experiment stations nowadays nor ARS laboratories develop hybrids," says Barry. "Public researchers may develop a few inbred lines with a well-defined package of genetic traits, but the seed companies, once they get germplasm, might reassemble it into different genetic packages anyway."

MOECB2(S1)C5 was released as a germplasm source to help farmers obtain hybrids with resistance to second-generation borers as quickly as possible after the trait had been identified, says Barry.

Dean Barry is located in Room I-67, Agriculture Bldg., University of Missouri, Columbia, Mo. 65211.—(By Ben Hardin, Peoria, Ill.) ■

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